CMFRI

Winter School on

Towards Ecosystem Based Management of Marine Fisheries – Building Mass Balance Trophic and Simulation Models

INFORMATION ONLY

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Technical Notes

ESTIMATION OF SECONDARY PRODUCTION & BENTHOS

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Marine organisms can be categorized as benthic, planktonic or nektonic depending on their physical habitat and their mode of motility. Planktonic organisms are those that live suspended in the water column and that are sufficiently small and/or slow so as to be incapable of directed swimming. Thus, their distribution is considered to be controlled by physical processes, such as water currents and turbulent mixing. In addition, plankton can be divided further based on their nutritional modality. Autotrophic phytoplankton depends on light and chlorophyll to fix carbon dioxide into organic molecules, whereas heterotrophic zooplankton ultimately depends on the phytoplankton for their dissolved or particulate foodstuffs.

Detectable changes in the abundance or species composition of mesozooplankton may reflect fundamental changes in the ocean environment affecting phytoplankton. In turn, because zooplankton are eaten by larger animals, some of which are of commercial importance, changes in zooplankton communities can provide early indications of imminent changes in the food conditions for fish, birds and mammals.

Plankton are tiny open-water plants, animals or bacteria. The name, like the word *planet*, is derived from a Greek root that means, "wanderer." These organisms range in size from microscopic bacteria and plants to larger animals, such as jellyfish. Plankton generally have limited or no swimming ability and are transported through the water by currents and tides. Plankton communities serve as a base for the food chain that supports the commercial fisheries.

Plankton can be divided into three major size classes:

? **phytoplankton**–microscopic plants and bacteria
? **zooplankton**–microscopic animals
? **macrozooplankton**–larger fish eggs and larvae and pelagic invertebrates

Plankton are often used as indicators of environmental and aquatic health because of their high sensitivity to environmental change and short life span. Phytoplankton are useful indicators of high nutrient conditions due to their propensity to multiply rapidly in the right conditions. Zooplankton are useful indicators of future fisheries health because they are a food source for organisms at higher trophic levels, such as finfish.

1. Phytoplankton

Like land plants, phytoplankton fix carbon through photosynthesis, making it available for higher trophic levels. The major environmental factors influencing phytoplankton growth are temperature, light and nutrient availability. Phytoplankton growth is usually limited to the *photic zone*, or the depth to which sunlight penetrates the water.

Phytoplankton can undergo rapid population growth or "algal blooms" when water temperatures rises in the presence of excess nutrients, which typically occurs near the coastal waters. While increased phytoplankton populations provide more food to organisms at higher trophic levels, too much phytoplankton can harm the overall health of the ecosystem. During these blooms, most of the phytoplankton die and sink to the bottom, where they decompose. This process depletes the bottom waters of dissolved oxygen, which is necessary for the survival of other organisms, including fish and crabs.

Phytoplankton are being used as indicators of environmental conditions because their populations are especially sensitive to changes in nutrient levels and other water quality conditions. A good picture of the current conditions in the sea can be derived by looking at phytoplankton indicators such as chlorophyll, primary production rates, biomass and species composition.

2. Zooplankton

Zooplankton are planktonic animals that range in size from microscopic rotifers to macroscopic jellyfish. Their distribution is governed by salinity, temperature and food availability. The smallest zooplankton can be characterized as recyclers of water-column nutrients and often are closely tied to measures of nutrient enrichment. Larger zooplankton are important food for forage fish species and larval stages of all fish. They also link the primary producers (phytoplankton) with larger or higher trophic-level organisms. The zooplankton community is composed of both primary consumers, which eat phytoplankton, and secondary consumers, which feed on other zooplankton.
Zooplankton can be classified into three size classes:

- **Microzooplankton**–(protozoans and rotifers) are usually less than 200 microcrons in size.
- **Mesozooplankton**–(including copepods and invertebrate larvae) are between 200 microns and 2 millimeters in size.
- **Macrozooplankton**–(including amphipods, shrimp, fish larvae and gelatinous zooplankton or jelly fish)are greater than 2 millimeters in size.

Zooplankton, like phytoplankton, make excellent indicators of environmental conditions, because they are sensitive to changes in water quality. They respond to low dissolved oxygen, high nutrient levels, toxic contaminants, poor food quality or abundance and predation. A good picture of the current conditions in the sea can be derived by looking at zooplankton indicators such as their biomass, abundance and species diversity.

Feeding habits of zooplankton

- Heterotrophs - Organisms that live off carbon fixed by primary production.
- Herbivores - Direct users of the primary producers, i.e. the phytoplankton.
- Detritivores - Consumers of dead organic matter produced by the senesence of pytoplankton, egestion of material from other zooplanktors (fecal material), or the remains of other zooplankton.
- Carnivores - Predators feeding on other zooplankton.

- Omnivores - Zooplankton that use a combination of food sources.

There are a variety of feeding stratagies in the zooplankton. Some such as copepods feed through a range of methods including setting up feeding currents with their legs that then pull phytoplankton cells past their mouths. Chaetognathas or arrow worms typically stay still in the water column and then lunge at a passing copepod to capture it with their sharp grasping spines. These saber-like spines are driven into the copepod during the ambush. Other organisms filter feed by pumping water through themselves or by the construction of large amounts of mucus upon which particles (phytoplankton, microzooplankton and detritus) become stuck. An example is the chordate salps that produce lots of mucus.

3. Benthic organisms

Studies on the benthic system are important in evaluating the health and productivity of the marine environment. Benthic macro invertebrates are the dominant groups in the marine sediments from the intertidal areas to the deep sea. Benthos is vital to the dynamics and health of the marine environment. Benthic organisms help in the deposition, breakdown and turn over of organic matter in the seabed and facilitate the recycling of nutrients. These organisms provide a key link in marine food webs. There exists a relationship between the benthic standing crop and the production of exploited demersal fishes and crustaceans.

The benthos is an aggregation of organisms living on or at the bottom of a body of water. The name *benthos* is derived from the Greek, meaning "depths of the sea." The benthic community is composed of a wide range of plants, animals and bacteria from all levels of the food web.

Benthic organisms can be divided into three distinct communities:

- **Infauna:** Plants, animals and bacteria of any size that live in the sediment.
- **Epifauna:** Plants, animals and bacteria that are attached to the hard bottom or substrate (for example, to rocks or debris); are capable of movement; or that live on the sediment surface.
- **Demersal:** Bottom-feeding or bottom-dwelling fish that feed on the benthic infauna and epifauna.

Benthic organisms link the primary producers, such as phytoplankton, with the higher trophic levels, such as finfish, by consuming phytoplankton and then being consumed by larger organisms. They also play a major role in breaking down organic material. Benthic algae and submerged aquatic vegetation (SAV) provide ideal habitat for juvenile fish. Benthic invertebrates are among the most important components of estuarine ecosystems and may represent the largest standing stock of organic carbon in the sea. Many benthic organisms, such as hard clams, softshell clams and bottom-dwelling fish, are the basis of commercial fisheries. Other bottom-dwelling organisms, such as polychaete worms and crustaceans, contribute significantly to the diets of economically important fish.

Infaunal benthic communities often are considered to be "just worms." In reality, however, these groups that inhabit the sediment include animals from all trophic levels–the primary producers, such as diatoms, and primary consumers, such as mollusks and worms; secondary consumers, such as worms and crustaceans; and "decomposers," such as bacteria and flagellates.

Benthic invertebrate communities are used as prime indicators of environmental conditions because:

- they have limited mobility and thus are unable to avoid adverse conditions;
- they live in sediments where they are exposed to environmental stressors, such as chemical contaminants and low dissolved oxygen levels;
- their life spans are long enough to reflect the effects of environmental stressors; and
- their communities are taxonomically diverse enough to respond to multiple types of stress.

Epifaunal Benthos

Epifauna are the most familiar of all the benthic organisms. They include the plants and animals one sees while wading in tidal pools or among pilings or rocks. These communities include seaweeds, oysters, mussels and barnacles; and snails, starfish and crabs. They also include animals that span a wide evolutionary range, from primitive sponges to early vertebrates (for example, tunicates, such as sea squirts). These varied organisms share an important characteristic: they live either attached to the hard substrate or move on the sediment surface.

The demersal community includes some of the most economically valuable fish. In order to adapt to life on the bottom, benthic fish have developed some of the most diverse physical characteristics found in any fish community. Soft-bottom fish include the flounders, puffers, searobins and cownose rays. Hard-bottom fish include those found near reefs, such as the oyster toadfish and the goby, which, when stationary, resemble rocks.

4. Sample collection

There are various methods for collecting samples for plankton and benthos analysis, depending on whether a quantitative or qualitative analysis is desired. With all methods, samples should be preserved soon after collection and where possible, live samples should also be examined. The methods for collecting samples are available in standard marine ecology text books.

5. Estimation of biomass

Biomass can be estimated either in wet weight or dry weight basis. While estimating wet weight, samples should be weighed immediately after blotting with tissue paper and for dry weight, samples should be dried using a hot air oven.

Zooplankton:

All zooplankton are delicate and easily damaged, so sample handling should be as gentle as possible. Since the zooplankton samples may not be counted for some time after they are returned to the laboratory, and since we hope these samples serve as a long-term, archive of national and international importance, the long-term maintenance of all of the organisms in each sample is a high priority. We recommend identifying and counting the samples under a dissecting microscope with dark-field illumination. Therefore, staining is not routinely required.

If one wants to know the total number of species in each sample, then the entire sample should be examined. If only a subsample will be analyzed, for abundance determination for example, there are a number of acceptable sample splitting routines one can follow. Recommended sub-sampling devices are the Folsom plankton splitter and the Motoda box splitter (Omori and Ikeda, 1984).

Biomass has commonly been expressed by settled volume, displacement volume, wet weight, dry weight, ash-free dry weight (organic weight), or carbon weight. The usual measure after fixing a sample has been its settled volume, displacement volume, or wet weight. The term biomass is often inappropriately used synonymously with the wet weight. In most cases, however the biomass is measured to determine the productivity and nutritional condition of the species in question and to assess the role of the species in the food web. In this sense biomass is expressed as settled volume, displacement volume, or wet weight is not always adequate because considerable variation occurs in these values due to manner of treatment and the composition of organisms. Furthermore, the measurement includes ash and other materials of low nutritive value.

In **settled-volume measurement** the sample is poured into a graduated cylinder or sedimentation tube of 50-100ml in volume, gently stirred with a glass rod, allowed to settle for 24 hr, and settled volume read. In case of **displacement-volume measurement**, the volume of the total water containing the plankton sample is first measured, after which the water is removed and its volume measured separately. The difference in volume is due to plankton. The above two methods not only include the absolute volume of the plankton but also the water between the organisms.

In case of **wet weight**, the weight of plankton is determined after eliminating as much surrounding water as possible. The water can be eliminated by vacuum filtration and by blotting the sample with filter paper (the filter paper is replaced when no more water can be absorbed by the paper). Care should be taken not to compress the plankton and damage the specimens to rush dehydration. The plankton sample without the adhering water is then weighed. The value is expressed as mg/m^3.

In case of **dry weight**, live specimens should always be weighed with this measurement, as the changes in the dry and organic weights as well as chemical composition of formalin- preserved specimen are considerable. The dried and weighed sample could not be used for species identification, in such case you have to go for duplicate samples. In case of preserved samples, samples not more than a month is used.

Procedure: A pyrex holder for membrane filters or similar filtration unit may be used to drain the water. A glass fiber (GF) filter with smaller or same mesh size of that of plankton net is weighed and then moistened on the filter holder with distilled water. The sample is added and sucked dry at about 250mmHg. When no more water can be eliminated, salt contained in any water remaining between specimens is eliminated with an isotonic ammonium formate (6.0 – 6.5 % W/V) rinse, which is also removed by suction. For specimens with harder outer covering (Crustaceans) sea salt can be eliminated with quick rinse with distilled water (prolonged rinsing will lead to loss of body fluids and dry weight). The specimens are large; it can be put in a bag of nylon plankton gauge and immersed for a short time in isotonic solution. After removal of rinse, the specimens are dried to a constant weight in an oven at 60°C.

In case of dry **organic weight (Ash-free dry weight)**, a known weight of the dry sample is ashed to a constant weight in a crucible at 450-500°C in an electric furnace. After it is completely ashed, the material is cooled in desicator and then weighed. The dry organic weight is obtained by subtracting the ash weight from the dry weight.

Benthic biomass:

The benthic organisms collected should be washed in seawater and sieved over five and one millimetre screens with round holes. The five-millimetre fraction should be sorted by hand, all fauna and biogenic structures were collected and preserved in 4% buffered formalin in seawater for later identification in the laboratory. The one millimeter fraction should be preserved without sorting. All calcareous poriferans should be preserved in 96 % ethanol.

In the laboratory, the organisms should be sorted and transferred to 80% ethanol. They should be later identified to the lowest possible taxonomic level, counted and weighed. Since marine macro-benthos seldom has great lipid stores they lose relatively little biomass during storage and biomass loss is therefore expected to be relatively evenly distributed in all samples. Weight should be measured by picking up the respective animals, removing excess water using paper tissue and then weighing. All individuals of the same species from one station should be weighed in one group. Animals with shells can be weighed with their shell. Biomass should be expressed in g/m^2.

For further reading:

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